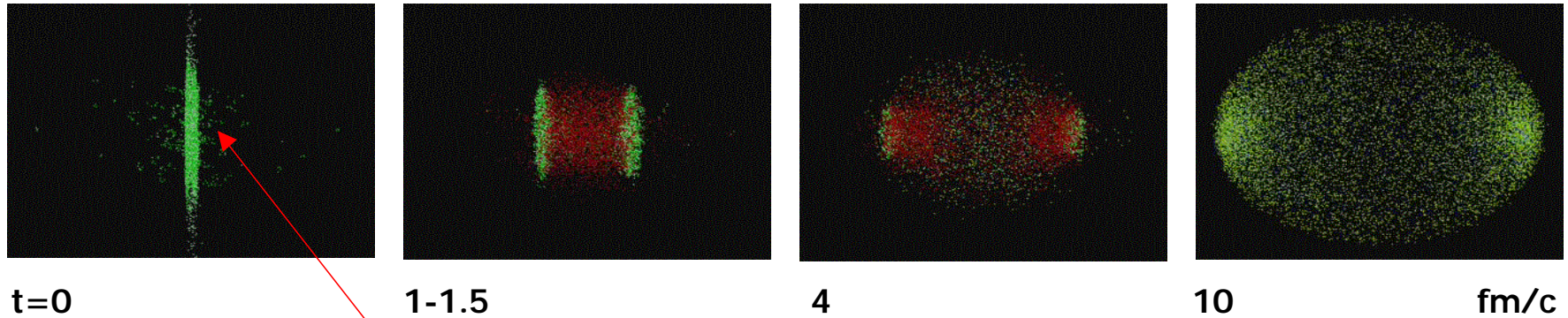


# 1 Au+Au Collision



partonic stage

hadronic stage

QM ( $\Delta x \Delta p < h$ ) formally induces  $v > c$

0. nuclei Lorentz contracted in lab. frame
1. hard parton scattering (qq,gg,qg)
2. hot cylinder (boost invariance assumed)
3. soft partons from energy at (0,0,0)  
beam remnants peaked forward/backward
4. freezeout: all partons  $\rightarrow$  particles

## Early time scales $t < 1 \text{ fm}/c$

- graceful disorder followed by QCD self-organization
- jet production (parton scattering).
- heavy quark production (s,c,b)
- Before equilibration  
 $E/N \sim \text{constant}$ , no temperature defined.  
max. temperature = Hagedorn  $T$  ?
- After equilibration.  
 $E/N \sim T$ ,  $N/V \sim T^3 \sim 1/t$ ,  $T \sim 1/t^{1/3}$
- compare to cosmological, primordial phase  
 $T \sim 1/t^{1/2}$  for radiation dominated universe  
 $T \sim 1/t^{2/3}$  for matter dominated universe
- Initial and final entropy is same !  
Thus  $N_{\text{gluons}}$  (partonic stage) =  $N_{\text{pions}}$  (hadronic stage)
- QGP expected around  $t \sim 1 \text{ fm}/c$  ( $\epsilon \sim 2\text{-}3 \text{ GeV}/\text{fm}^3$ )
- $\pi$  freeze-out  $t \sim 8\text{-}9.5 \text{ fm}/c$ , p/n freeze-out  $\sim 10\text{-}15 \text{ fm}/c$

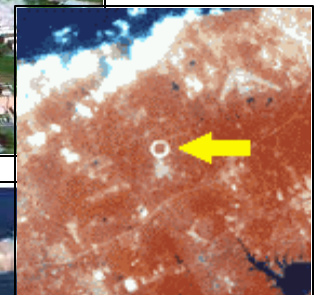
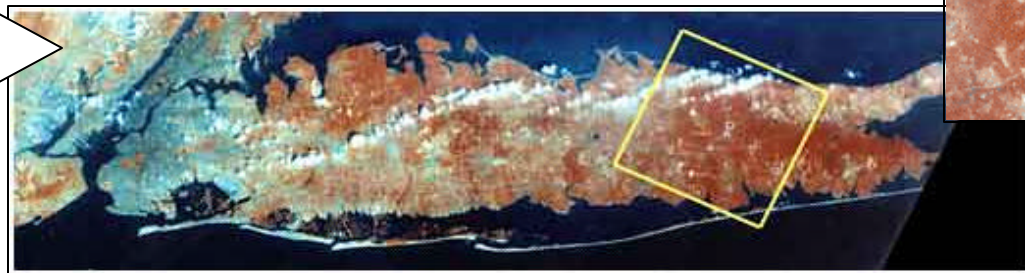
**Au+Au**

2000:  $\sqrt{s_{NN}} = 130$  GeV

2001:  $\sqrt{s_{NN}} = 200$  GeV



New York





# The STAR Experiment

$$y \approx \eta \approx 1$$

24 sectors x 5692 rf pads x 350 t bins  
= 47,812,800 pixels

**Time  
Projection  
Chamber**

FTPCs

Vertex Position  
Scintillators (TOF)

Trigger Barrel  
(TOF)

Silicon  
Vertex  
Tracker

RICH

Magnet  $B = \pm$   
0.5 T

Barrel EMC

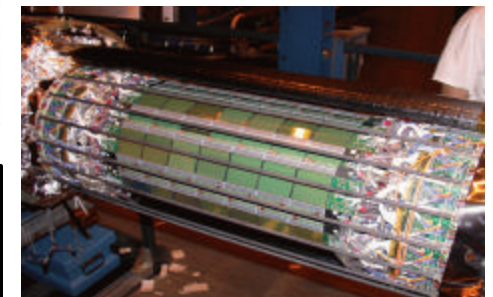
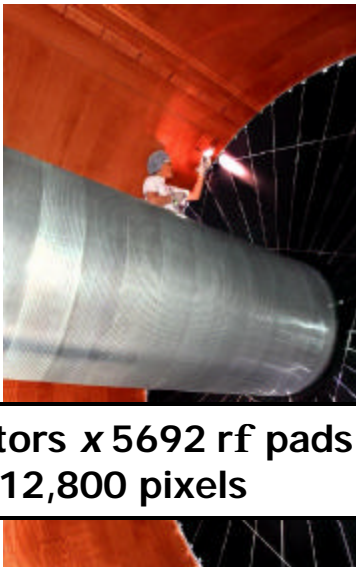
Endcap EMC

ZDC

ZDC

2 m

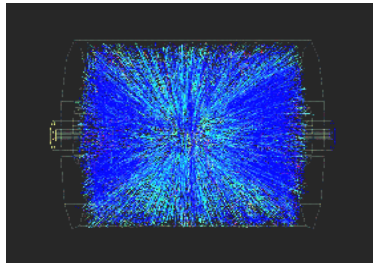
4 m





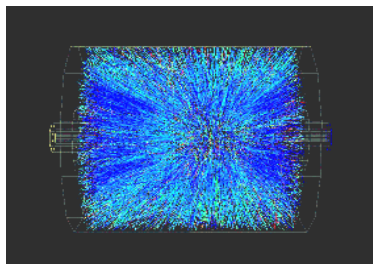
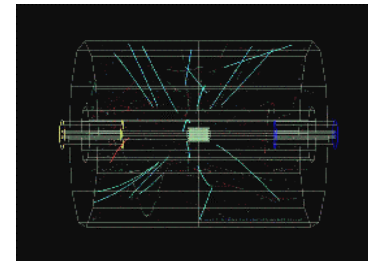
# Data set.

hot partonic/nuclear matter



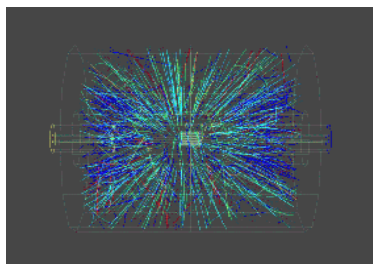
Au+Au  
 $\sqrt{s}=130$  GeV  
 $N_{\text{Event}}=0.7$  Mio

pp  
 • un-polarized pile-up !  
 • vertical pol. 391/nb  
 • longitudinal pol. 373/nb  
 (spin flip snake)

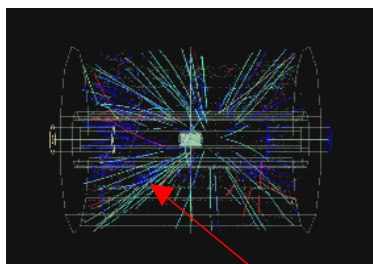


Au+Au  
 $\sqrt{s}=200$  GeV  
 $N_{\text{Event}}=3.2$  Mio

Level-3 trigger, rare probes  
 EMC jet trigger



Au+Au  
 $\sqrt{s}=19.6$  GeV  
 $N_{\text{Event}} \sim 20k$



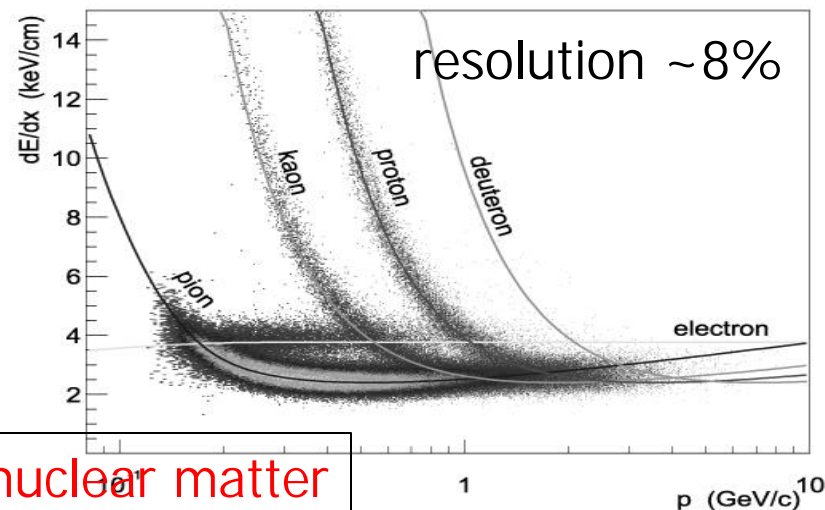
d+Au  
 $\sqrt{s}=200$  GeV  
 $N_{\text{Event}}=35$  Mio.

asym !

cold partonic/nuclear matter

jet

## Particle Identification: dE/dx



## The QGP.

- deconfined (in QCD sense -> no bag anymore)
- 02/2000 CERN announced "QGP evidence"
  - strangeness enhancement (s-quark condensation in high T)
  - $J/\psi$  suppression (gluon break-up)
- QCD phase transition

### 1<sup>st</sup> order:

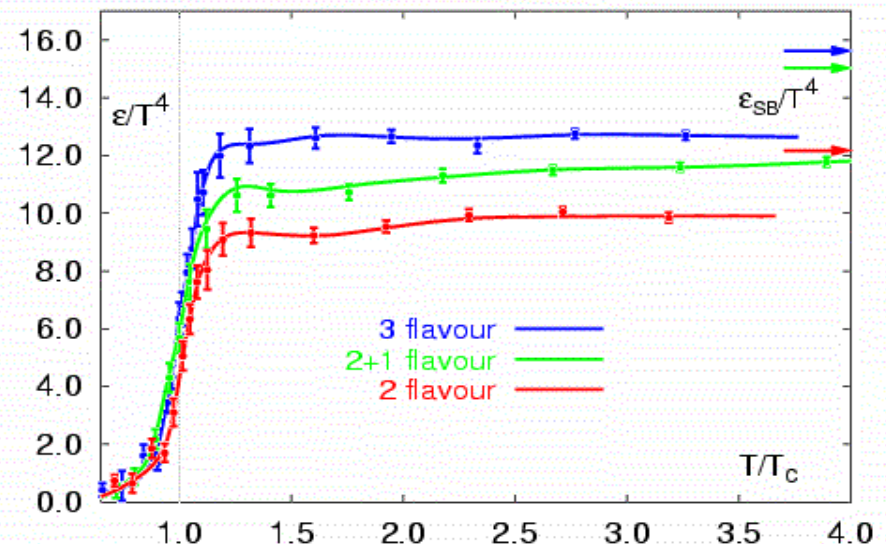
mixed phase

hadrons with QGP bubbles

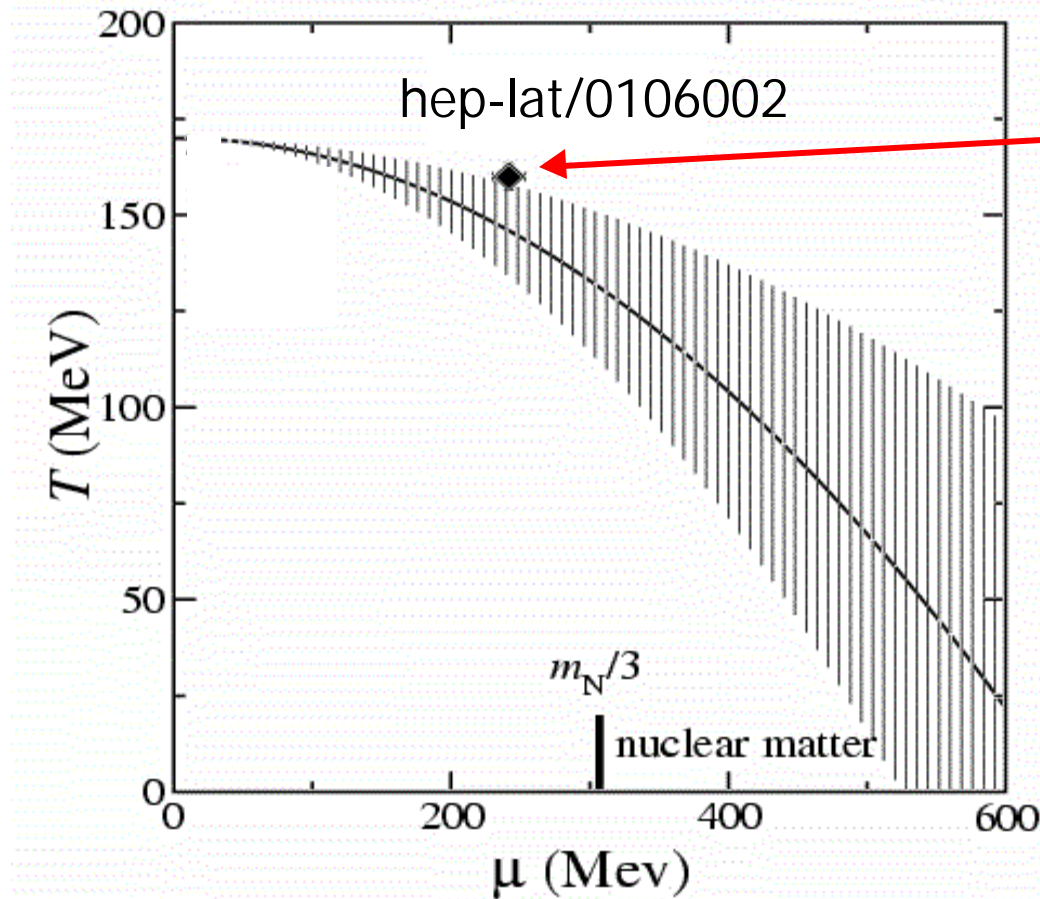
### 2<sup>nd</sup> order:

from pure 100% phase #1  
to pure 100% phase #2

- predicted by lattice QCD  
 $T_c = 160 \pm 3.5$  MeV



## Where is the critical point ?



$$\begin{aligned} T_c &= 160 \pm 3.5 \text{ MeV} \\ \mu_b &= 725 \pm 35 \text{ MeV} \\ \epsilon &= 0.3 - 1.3 \text{ GeV/fm}^3 \end{aligned}$$

Phase boundary lattice QCD:  
Allton et al.  
hep-lat/0204010

At RHIC we are not near the critical point  
no dramatic  $N_{\text{charged}}$  event-by-event fluctuations expected.



## Thermal fit Result:

$T=176 \text{ MeV (130 GeV)}$ ,  $T=177 \text{ MeV (200 GeV)}$

$\mu_B = 41 \text{ MeV (130 GeV)}$

$\mu_B = 29 \text{ MeV (200 GeV)}$

$T = 2.1 \cdot 10^{12} \text{ K}$

*Sun*

$15.6 \cdot 10^6 \text{ K}$

*Supernova*

$\sim 10^9 \text{ K}$

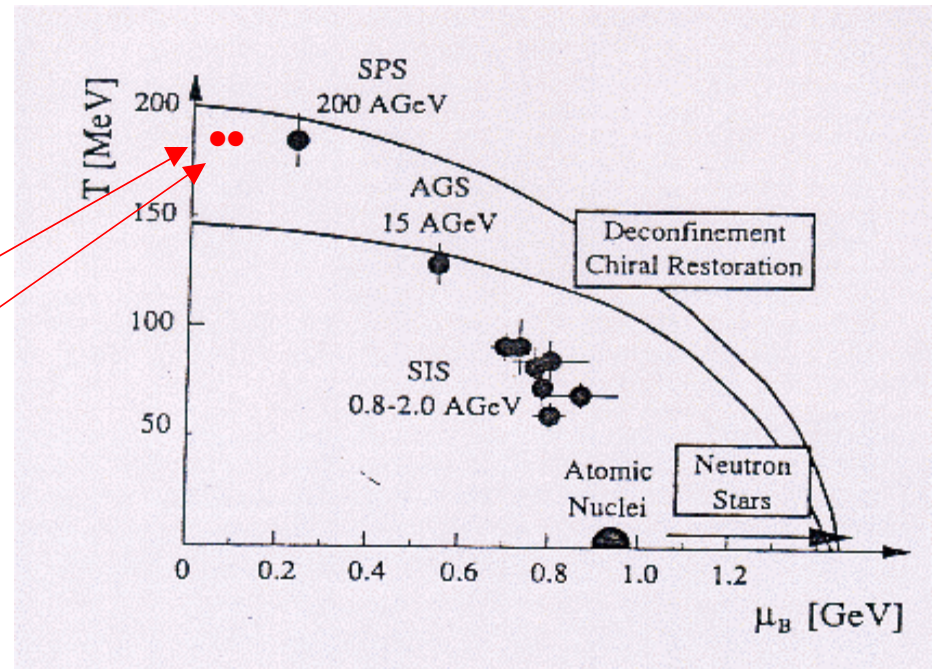
*Plasma fusion*

$55 \cdot 10^6 \text{ K}$

*Laser fusion*

$4 \cdot 10^6 \text{ K}$

200 GeV  
130 GeV



Universe:

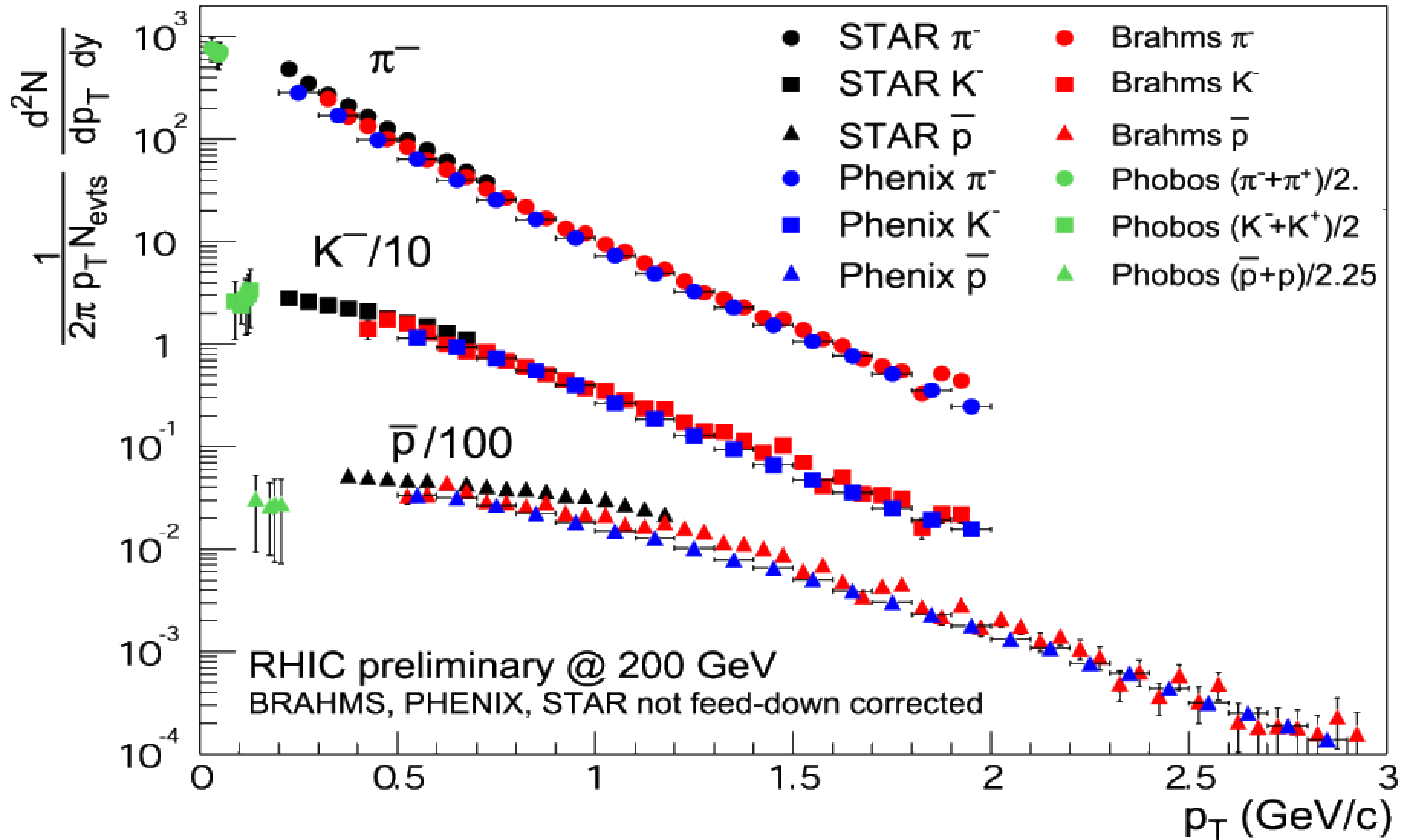
$T_{\text{Planck}} = 1.4 \cdot 10^{34} \text{ K}$

but maybe Hagedorn-limited  $\sim 1/R$

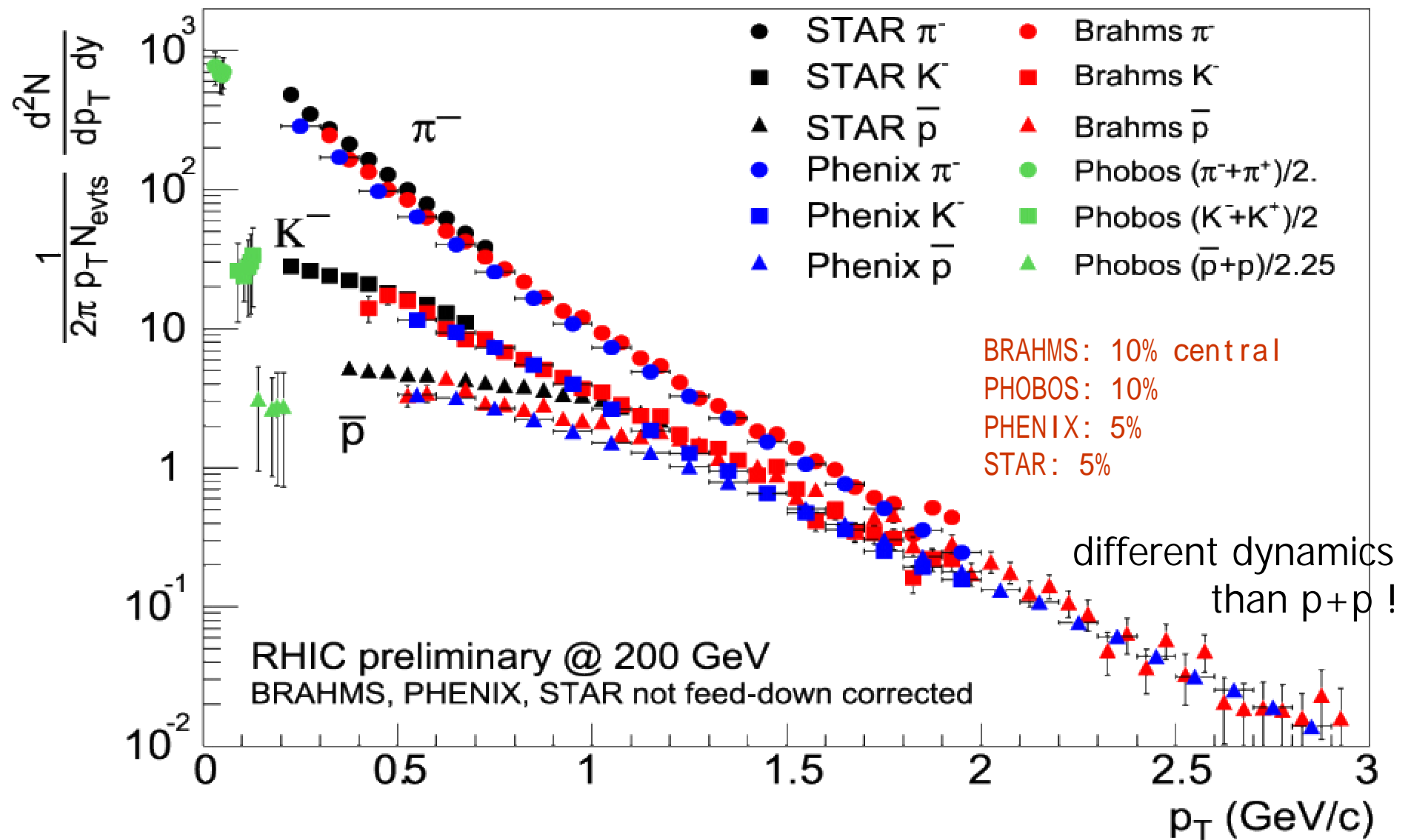
$$\mu_B \sim N_{\text{Baryon}} - N_{\text{Anti-Baryon}}$$

$$\mu_B \sim N_{\text{sea}} / N_{\text{valence}}$$

# $p_T$ Distributions $p+p$ ( $\sqrt{s}=200$ GeV)

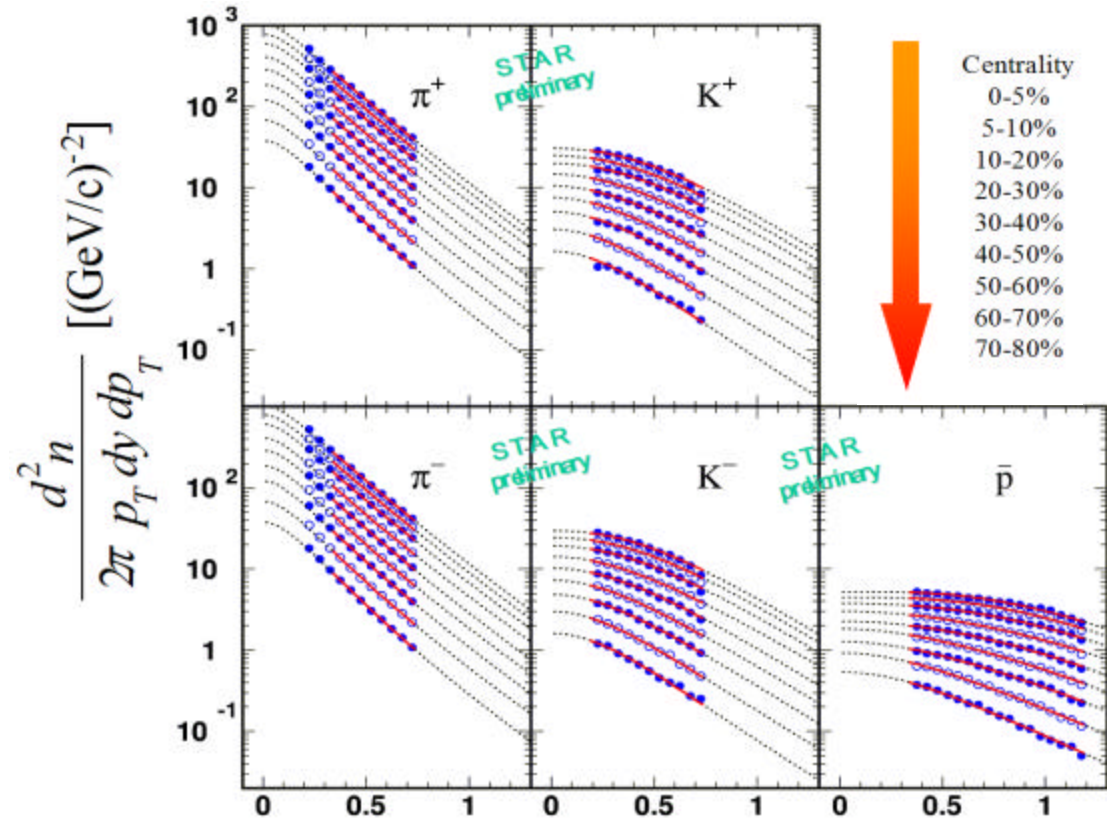
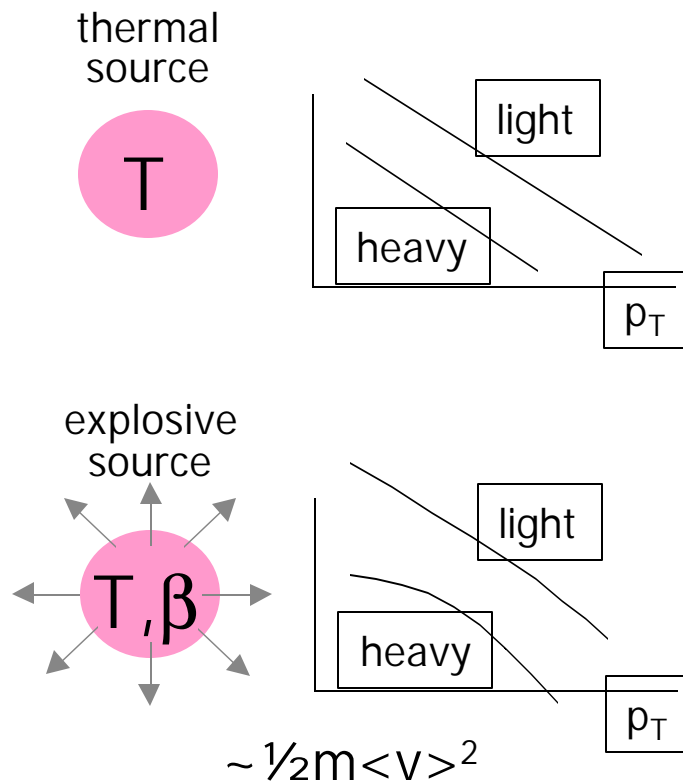


# $p_T$ Distributions Au+Au ( $\sqrt{s}=200$ GeV)





# From light to heavy particles - shape changes.



$$\frac{1}{m_T} \frac{dN}{dm_T} \propto A \exp \left( -\frac{m_T}{T} \right)$$

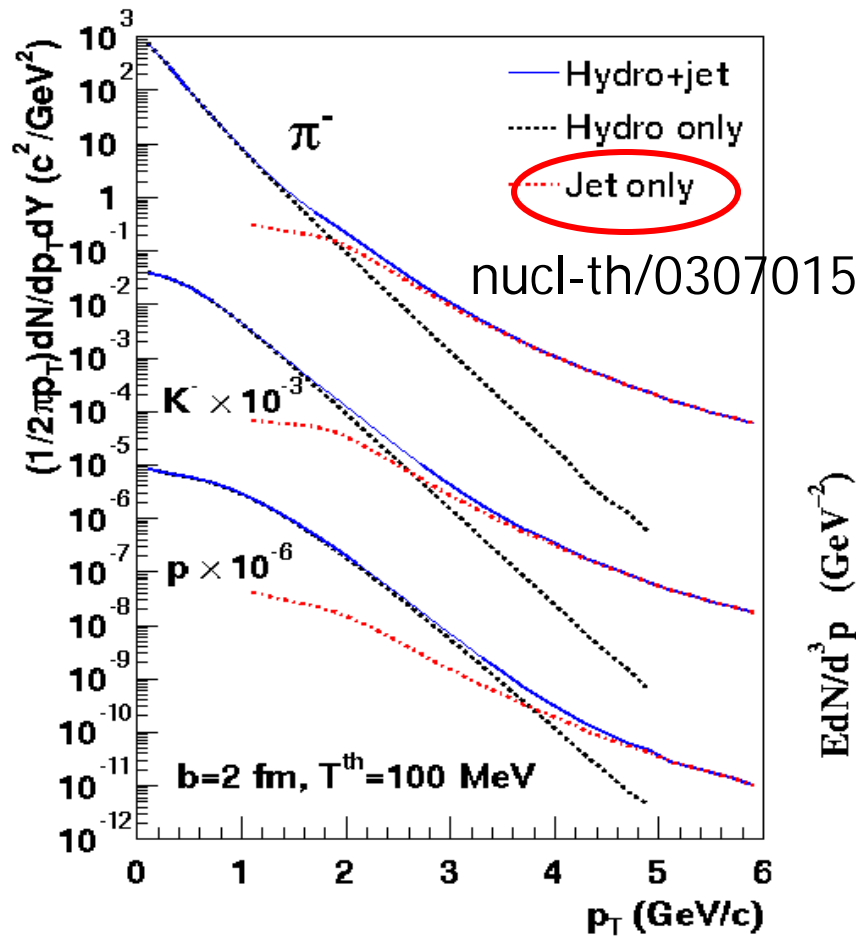
- For fit of Temperature use  $m_T$  instead of  $p_T$

$$m_T = \sqrt{p_T^2 + m^2}$$

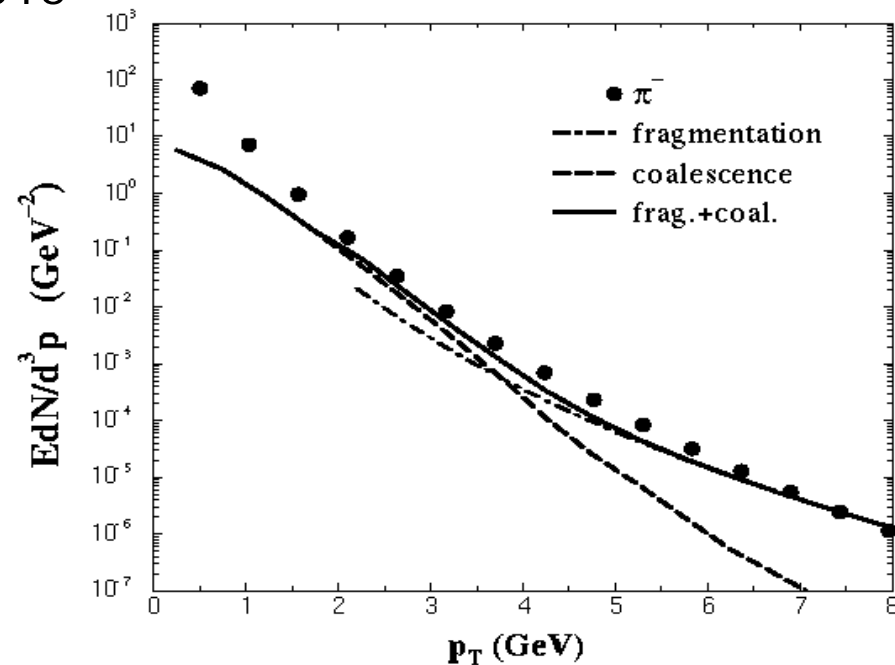
# How might parton dynamics influence spectral shape ?

$dN/dy = \text{soft} + \text{hard}$  (predicts  $N_{200}/N_{130}=1.14$ , nucl-th/0108006)

$$dN/dy_{AA} = [ (1-X(s)) N_{\text{participant}} + X(s) N_{\text{binary}} ] dN/dy_{pp}$$

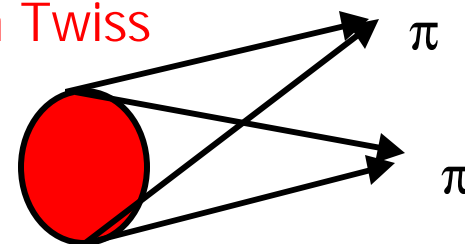


Possible parton coalescence  
(gluon wave functions overlap  
if saturated) nucl-th/0305024

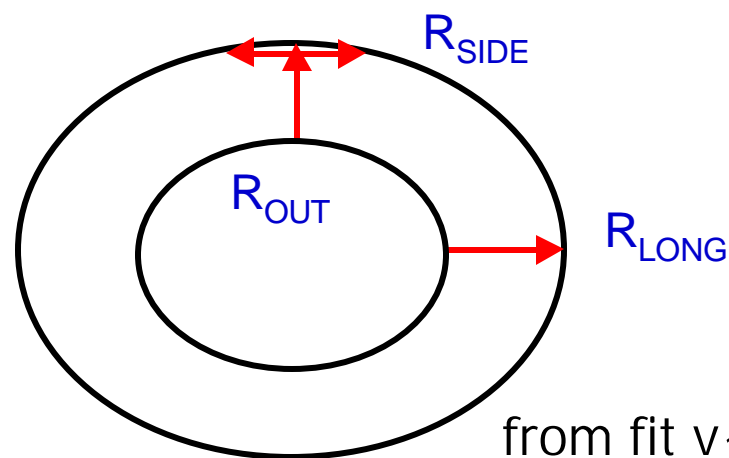


## What is the size ?

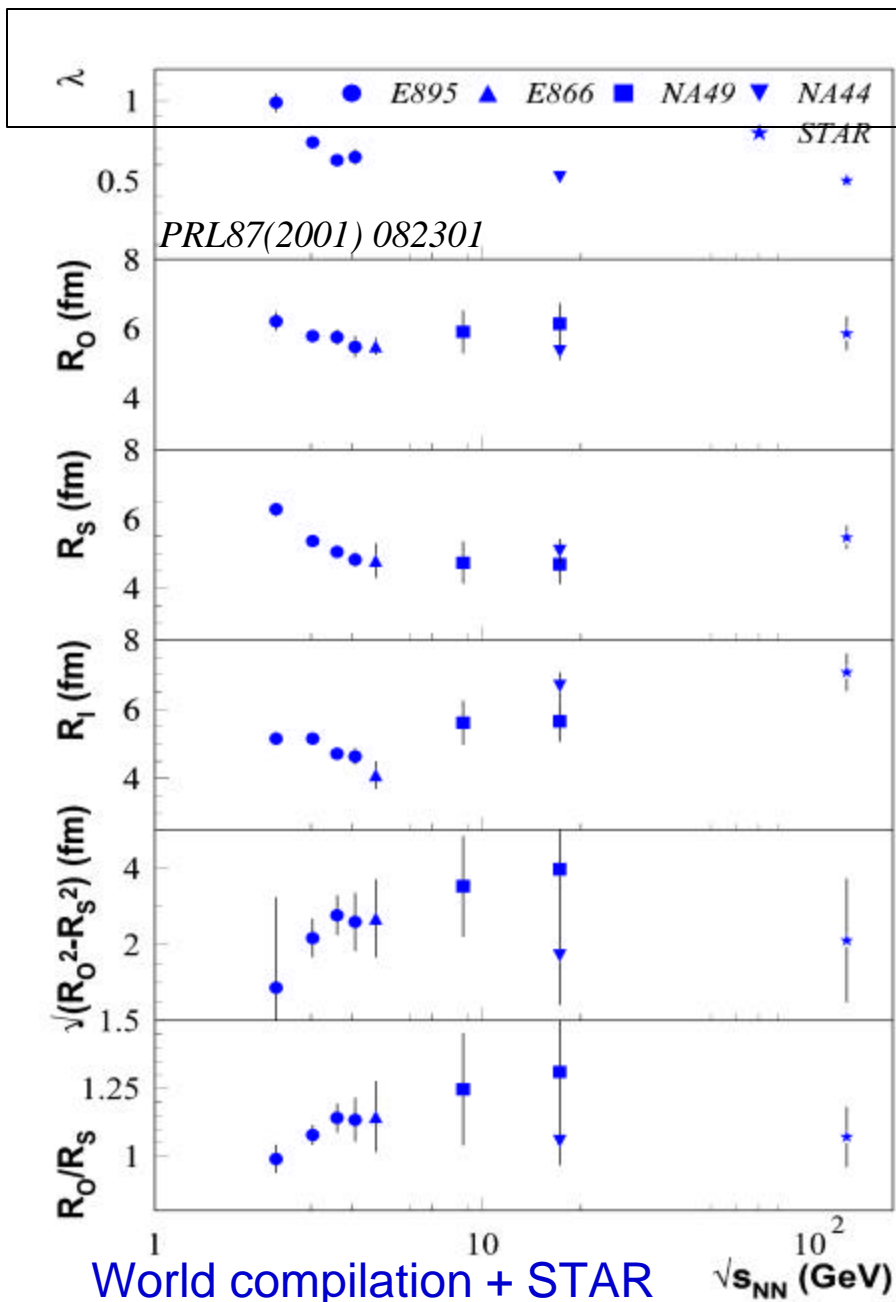
- Hanbury-Brown Twiss Interferometry



- Surprising:** Size roughly same  
AGS = SPS = RHIC  $R < 10$  fm
- Unexpected:**  $R_{\text{out}}/R_{\text{side}} \sim 1$   
explosive source, followed by  
short "freeze-out" =  
expanding shell ("blast wave")



from fit  $v \sim 0.55c$

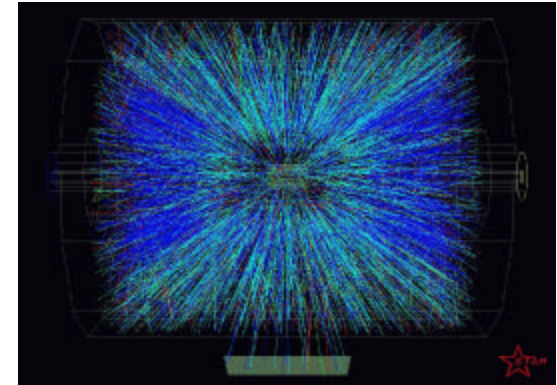




## What did we learn from the number of particles ?

- Initial and final entropy is same  
 $N_{\text{gluons}} (\text{partonic stage}) = N_{\text{pions}} (\text{hadronic stage})$

- perturbative QCD expectation  
 $N_{\text{charged}}(\sqrt{s}=200 \text{ GeV})$   
 $= \underline{1.14} \times N_{\text{charged}}(\sqrt{s}=130 \text{ GeV})$   
 fits well -> no QGP needed for interpretation



- but pQCD models need either/or
 

$$\frac{3\pi^2\alpha_s A}{2Q_{\text{Saturation}}^2} \times \frac{x \cdot G(x, Q^2(x))}{\pi R_A^2} = 1$$

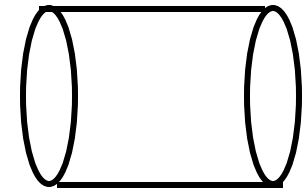
(2 gluons collide)

  - “high density QCD”  
 $\alpha_s^{\text{eff}}$  changes
  - “high temperature QCD”  
 $\alpha_s^{\text{eff}}$  changes  $\sim 1/(33-2N_f)\ln(T/T_{\text{crit}})$

both cases: gluons acquire “mass” (on-shell)

## What is the quark/gluon density @ $t=0$ ?

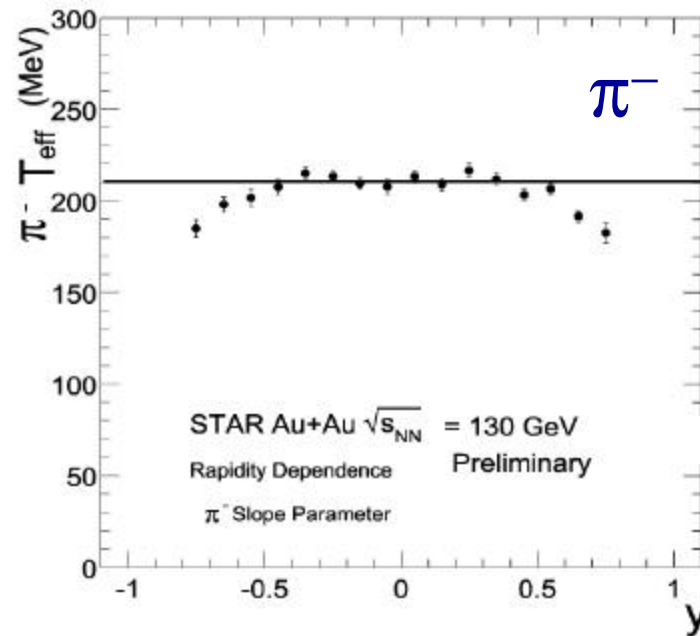
- we have  $N_{\text{charged}}$
- we have  $R$   
assume cylinder, lorentz-invariant rapidity  $y$   
 $t=0$   $\rho$ =infinite, but @  $t=0.2$  fm/c:  
 $\rightarrow \rho = 20/\text{fm}^3 = \underline{15} \times \rho[\text{cold Au}]$   
(hadrons definitely in-existent)
- What is the energy density ?  
we have average momentum  $\langle p \rangle$   
90%  $\pi$ , so assume  $m_\pi$ , then  $E^2 = m^2 + p^2$   
 $\rightarrow \epsilon \sim 5 \text{ GeV}/\text{fm}^3 = \underline{30} \times \epsilon[\text{cold Au}]$



$$\rho \approx \frac{dN}{dy} \frac{1}{\pi R^2 t}$$

better pQCD estimate:  $\epsilon \sim 18 \text{ GeV}/\text{fm}^3$  Phys. Lett. B 507(01)121  
SPS  $\epsilon \sim 3 \text{ GeV}/\text{fm}^3$ , predictions before RHIC start up to  $30 \text{ GeV}/\text{fm}^3$

## Boost-Invariance ?



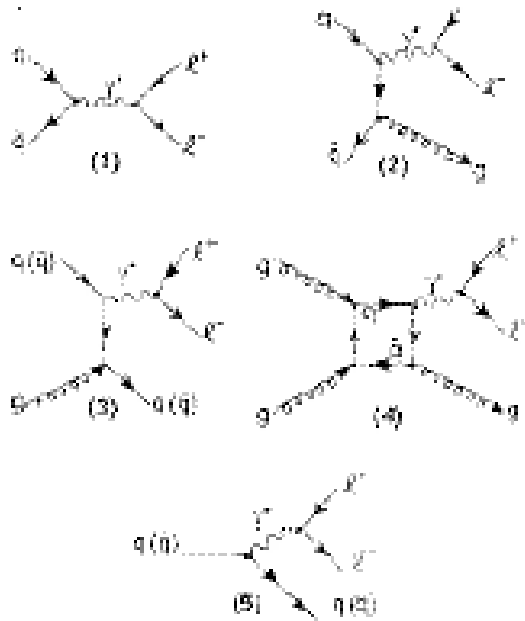
Boost invariance only achieved in small region  $|y| < 0.5$

- No surprise for protons:  
 $\bar{p}/p \sim 0.65$  means 2/3 come from pair production,  
but 1/3 comes from Au nuclei (de-accelerated)
- But surprise for pions !



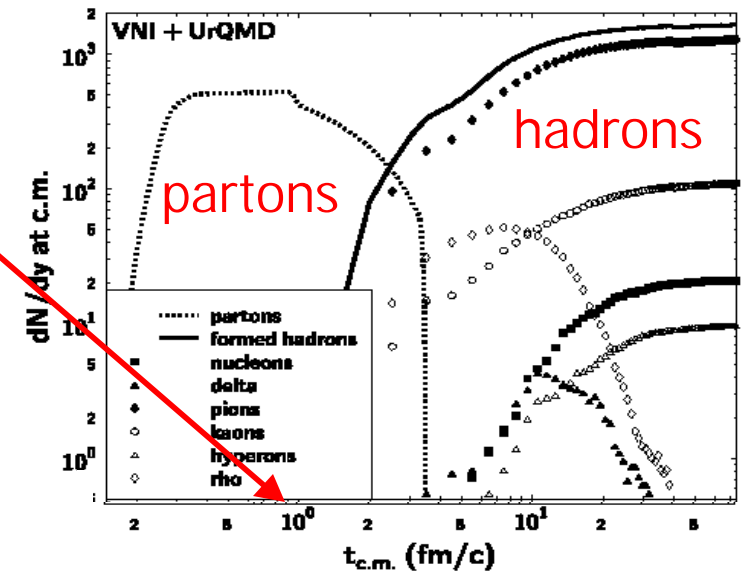
# Parton-Hadron Cascade in Au+Au

nucl-th/9907090



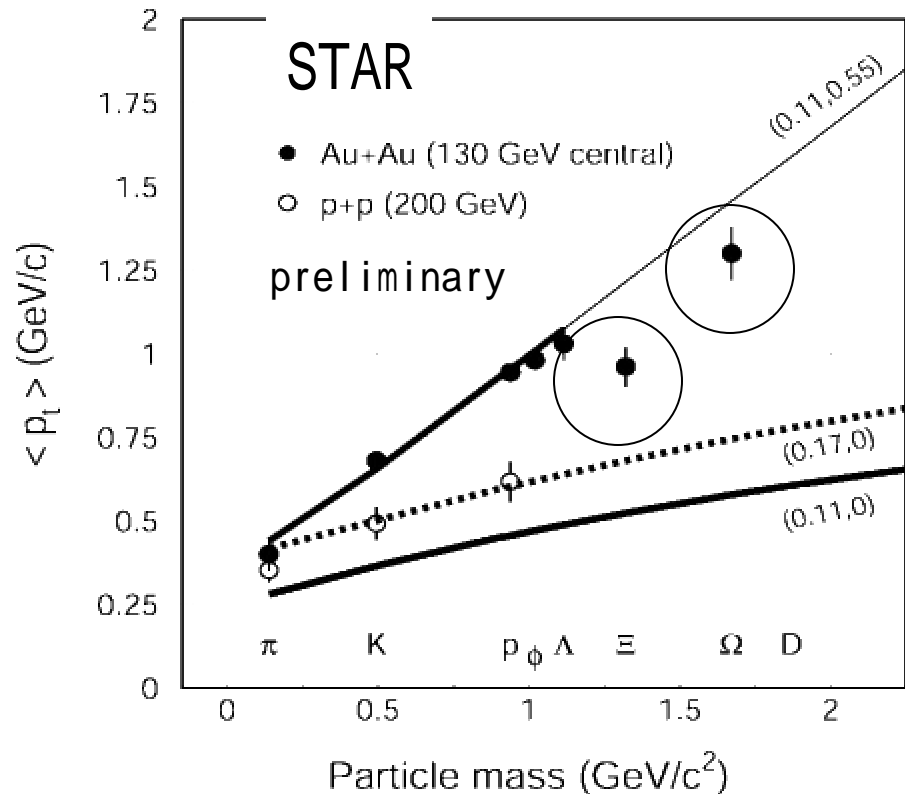
Phys. Rev. Lett. 70(93)1920

$t = 1 \text{ fm}/c$



- Dogma:  
ALL particles freeze out at the SAME  $T$ ,  
not dependent on (hadron) mass.
- If we observe different  $T$ , then
  - re-scattering cross sections are mass or flavor dependent (u,d vs. s quarks)
  - heavy quarks are produced early ( $T$  must be high enough)

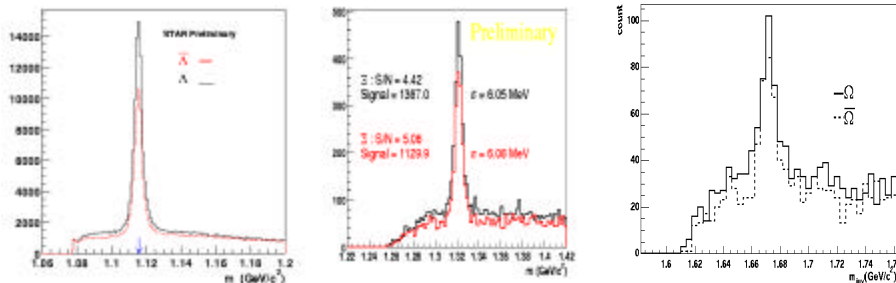
# Heavy baryons with 1,2 or 3 strange quarks.



blastwave fit  
 $T=110$  MeV,  $\beta=0.55$

$T=170$  MeV,  $\beta=0$   
 pp no rescattering,  
 no flow  
 no thermal equilibrium

$\Omega$  (sss) and  $\Xi$  (uss) deviate !

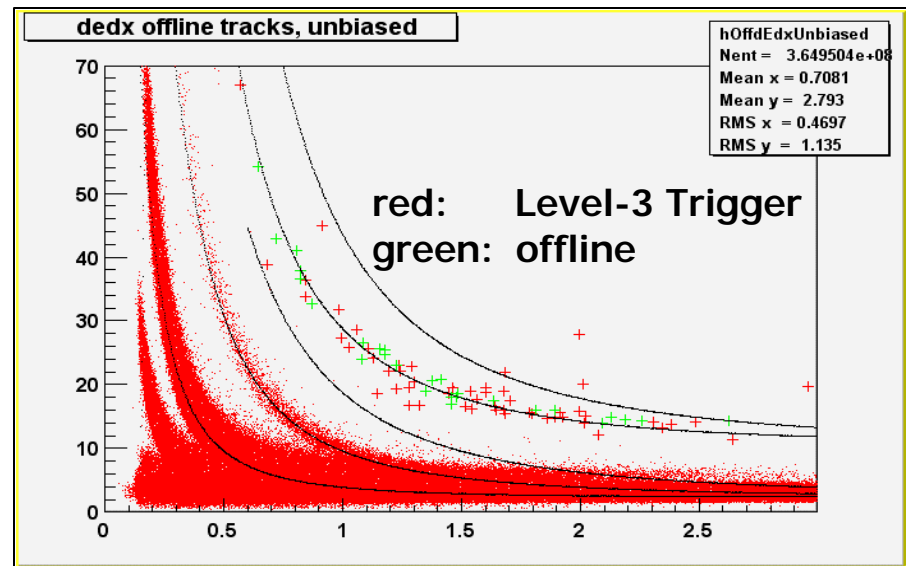


Early decoupling from  
 expanding hadronic medium ?  
 Or smaller re-scatter  $\sigma_{\text{elast}}$  ?  
 Or indication for partonic flow ?

## How do we create Anti-He ?

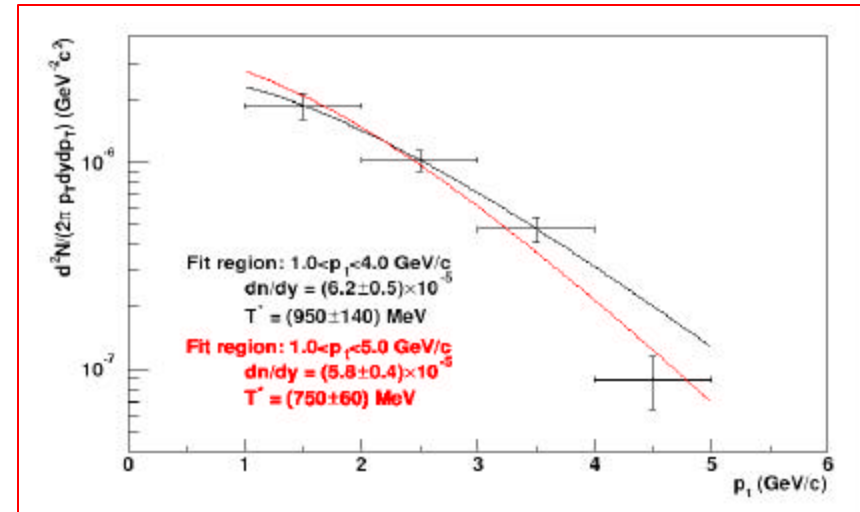
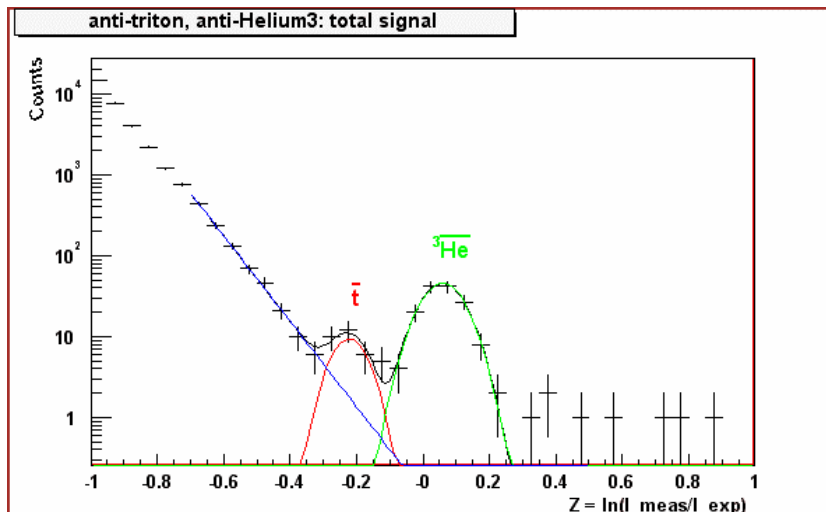
- cluster of particles can also be beam remnants, but cluster of anti-particles cannot
- Coalescence:  
 $N$  protons/neutrons  
overlapping wave functions  
( $\Delta x$  and  $\Delta p$  small)
- Ansatz  $N_{\text{deuteron}} = f \times N_{\text{proton}}$   
"penalty factor"  $f \sim 1/2500$
- Level-3 trigger system,  $\sim 4$  months:  
charge = -2  
(almost background free, but rare)
- total sample 2002  
     $\sim 160$  Anti-He<sup>3</sup>  
    no Anti-He<sup>4</sup> yet (would be first observation)

needs  $15 \times 10^6$  events



# Why is Anti- $^3\text{He}$ Temperature so high ?

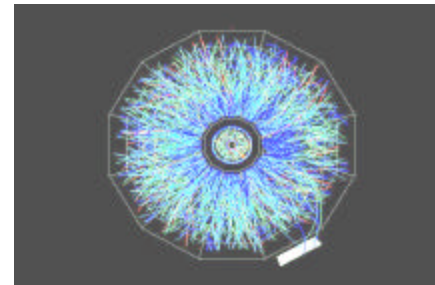
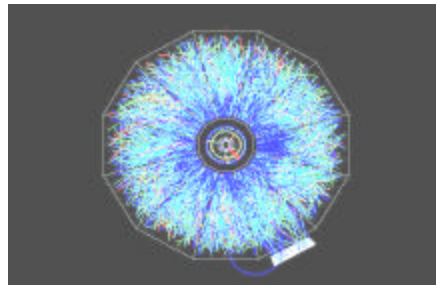
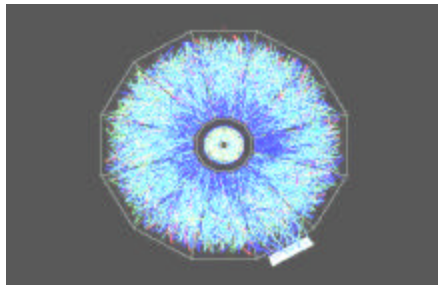
- world sample increased by factor  $\sim 10$
- very high  $T > 750$  MeV ( $m_T$  scaling  $\sim$  heavy = hot)
- $\psi$  overlap volume:  $R^3 = 107 \pm 7 \text{ fm}^3 \rightarrow R = 4.8 \text{ fm}$   
but proton/neutron freeze-out late  $t \sim 15\text{-}20 \text{ fm}/c$   
 $\rightarrow$  early coalescence (parton vs. baryon coalescence) ?  
**NO!**  $p_T$  distribution is deformed by heavy mass ( $1/\text{slope} \neq T$ )



$$p_T^2 = \sqrt{m_T^2 - m^2(^3\text{He})}$$



# Heavy quarks. Search for Upsilon. Production 90% by gg at $t \sim 0.1$ fm/c.

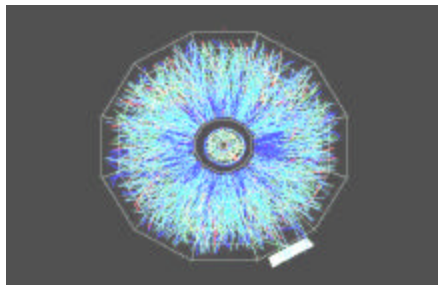
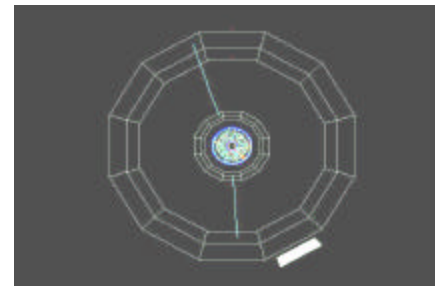
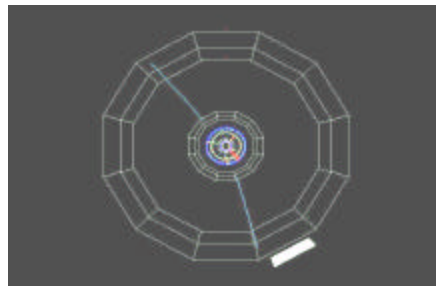
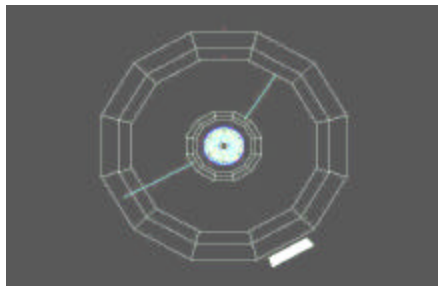


**Upsilon  $\rightarrow$  l+l-  
candidates**

Run 2241022  
Event #4699  
m=10.21 GeV

Run 2243027  
Event #1645  
m=9.68 GeV

Run 2244029  
Event #1570  
m=9.25 GeV



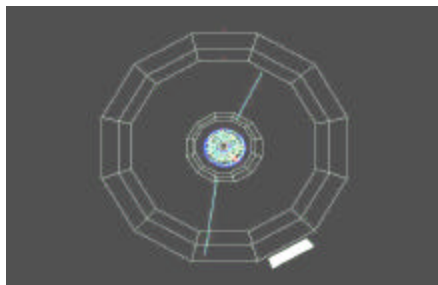
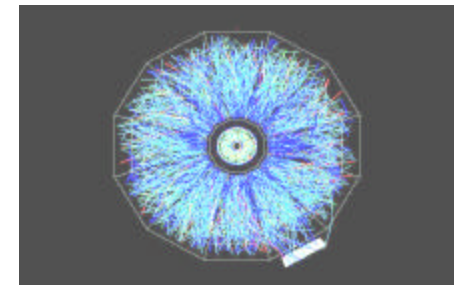
**$p^+ p^-$  candidate**

Run 2244032 Event #3420  
m=9.38 GeV

$dE/dx < 1.4e-5$  keV/cm  
 $P_{PID}(\text{lepton}) < 3\%$

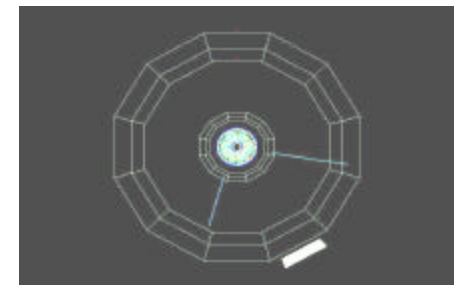
**Drell-Yan candidate**

Run 2252020 Event #8718  
m=10.02 GeV



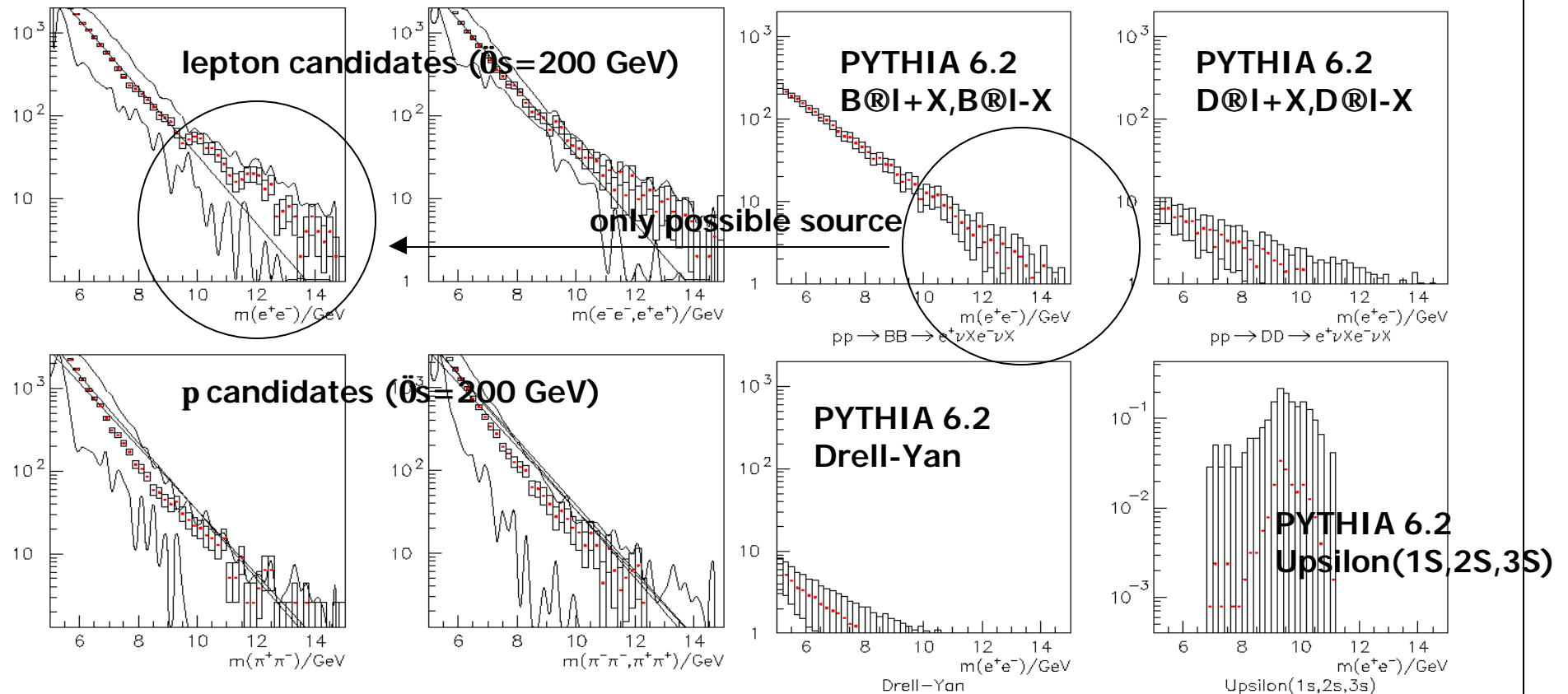
**Au+Au  
 $\sqrt{s_{NN}} = 200$  GeV**

**DF = 78°**



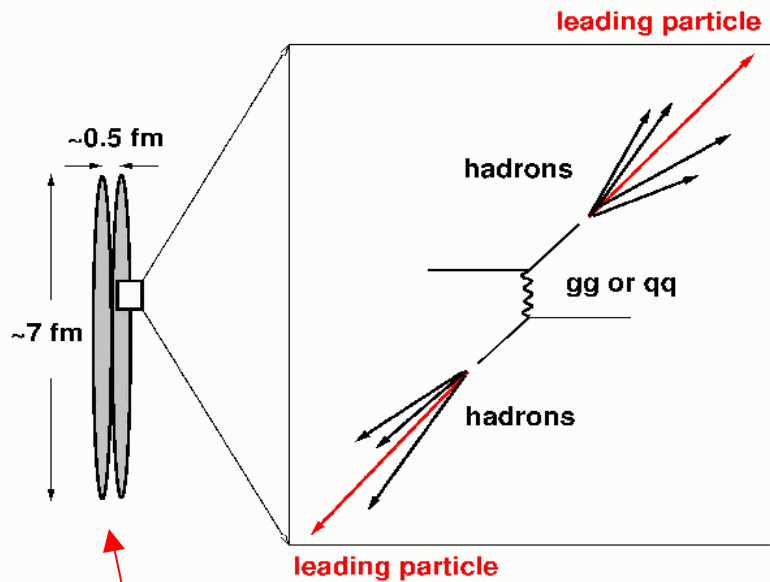
# Heavy Quarks: Di-Lepton Mass Distributions $m > 5$ GeV

Evidence for unlike-sign lepton pair enhancement at mass  $> 9$  GeV.

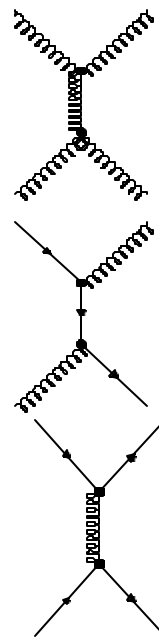


## Jets: gg or qq scattering at very early $t \sim 0.2 \text{ fm}/c$ .

- $\sqrt{s}(\text{RHIC}) \sim 10 \cdot \sqrt{s}(\text{SPS})$  - for the first time  $\sigma_{\text{jet}}$  accessible in AA collisions
- pQCD  $\sqrt{s}=200 \text{ GeV}$ :  $\sim 405$  gluons,  $\sim 132$  quarks,  $\sim 38$  anti-quarks



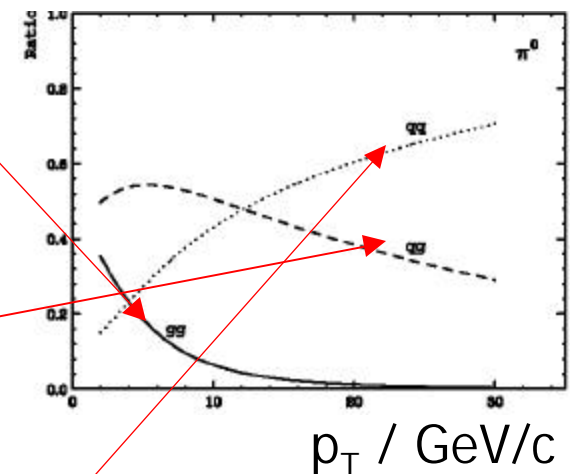
Cylinder at  $t \sim 0.2 \text{ fm}/c$  very flat.



$gg \rightarrow gg$

$qg \rightarrow qg$

$qq^{(\prime)} \rightarrow qq^{(\prime)}$



Color-1 ( $gg, qq$ ) and Color-8 ( $qqg, ggg$  in final states) contribute. Color-8 maybe inhibited by gluon saturation in medium.

## Jets at STAR (pp, $\sqrt{s}=200$ GeV)

2 jet (gg or qq)  
all tracks  $p_T > 1$  GeV/c

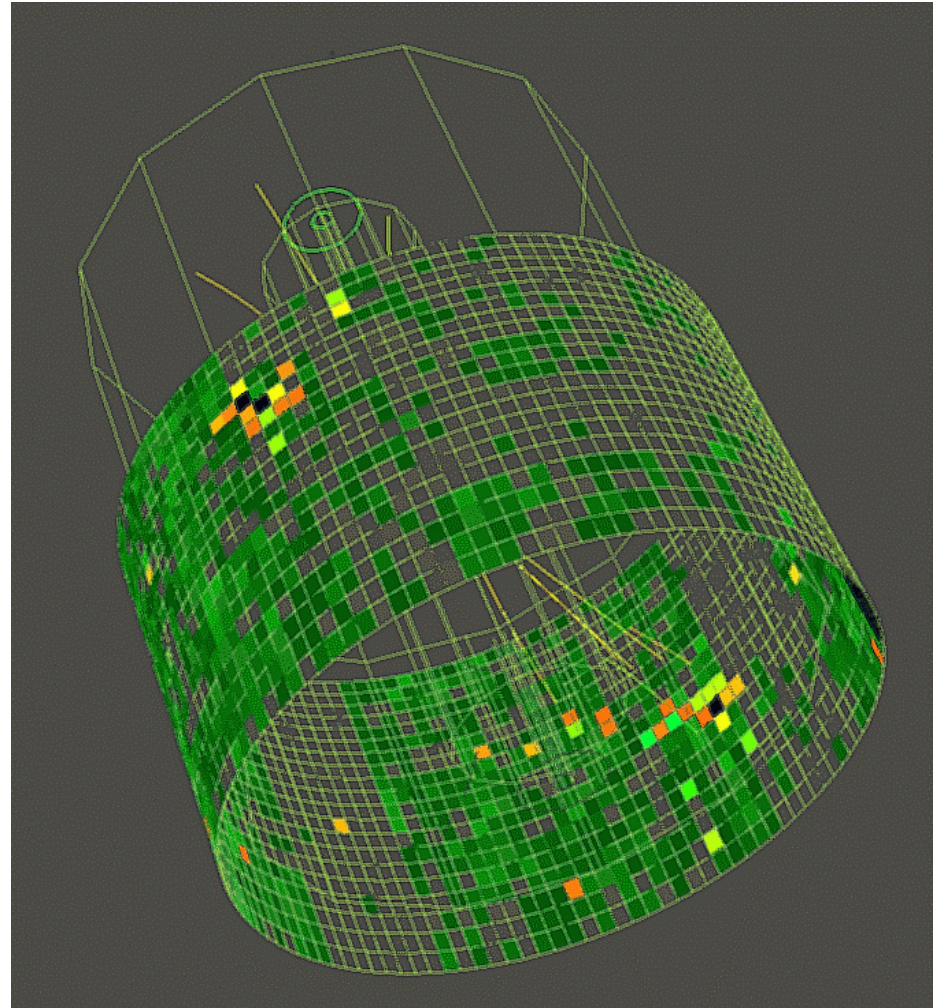
What about Au+Au ?

pQCD estimate

$E_T > 1$  GeV

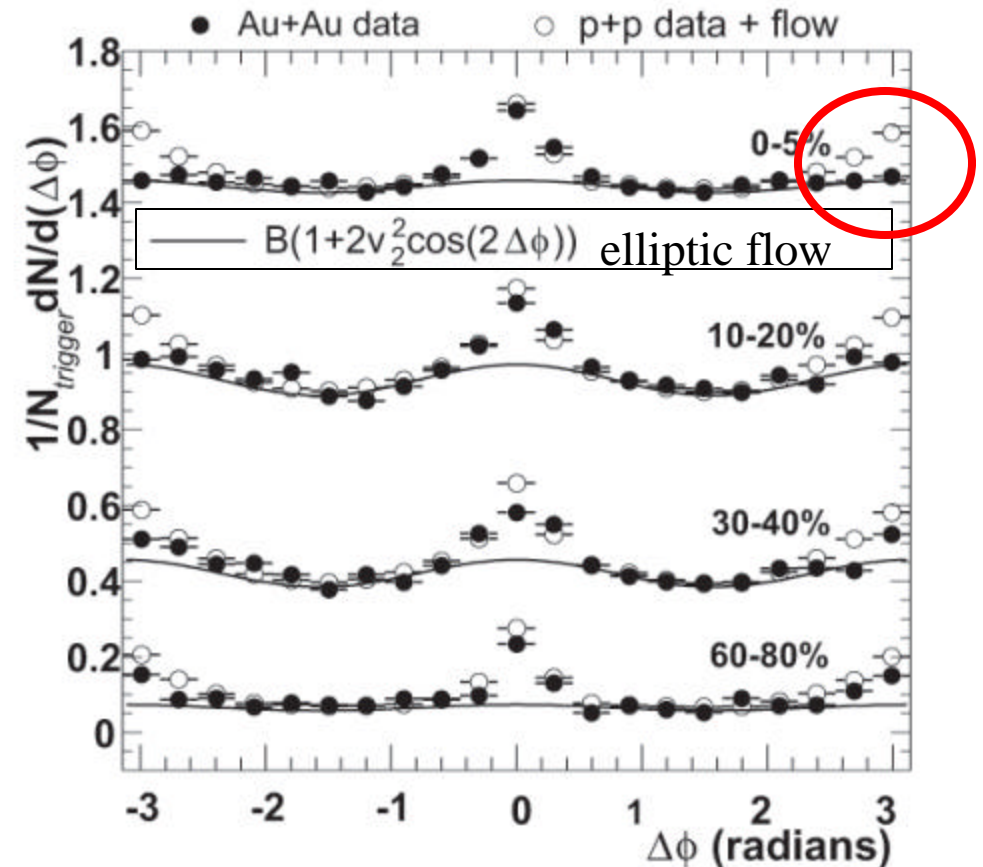
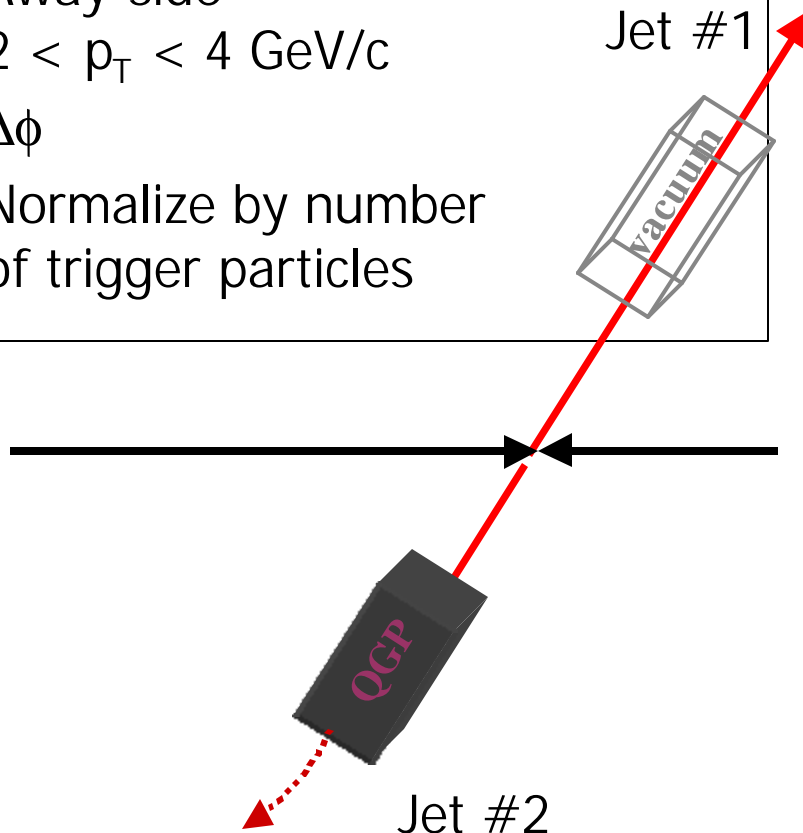
$N_{\text{Jet}} \sim 500$

almost impossible  
for jet finder algorithm.



## Back-to-back leading jet particles

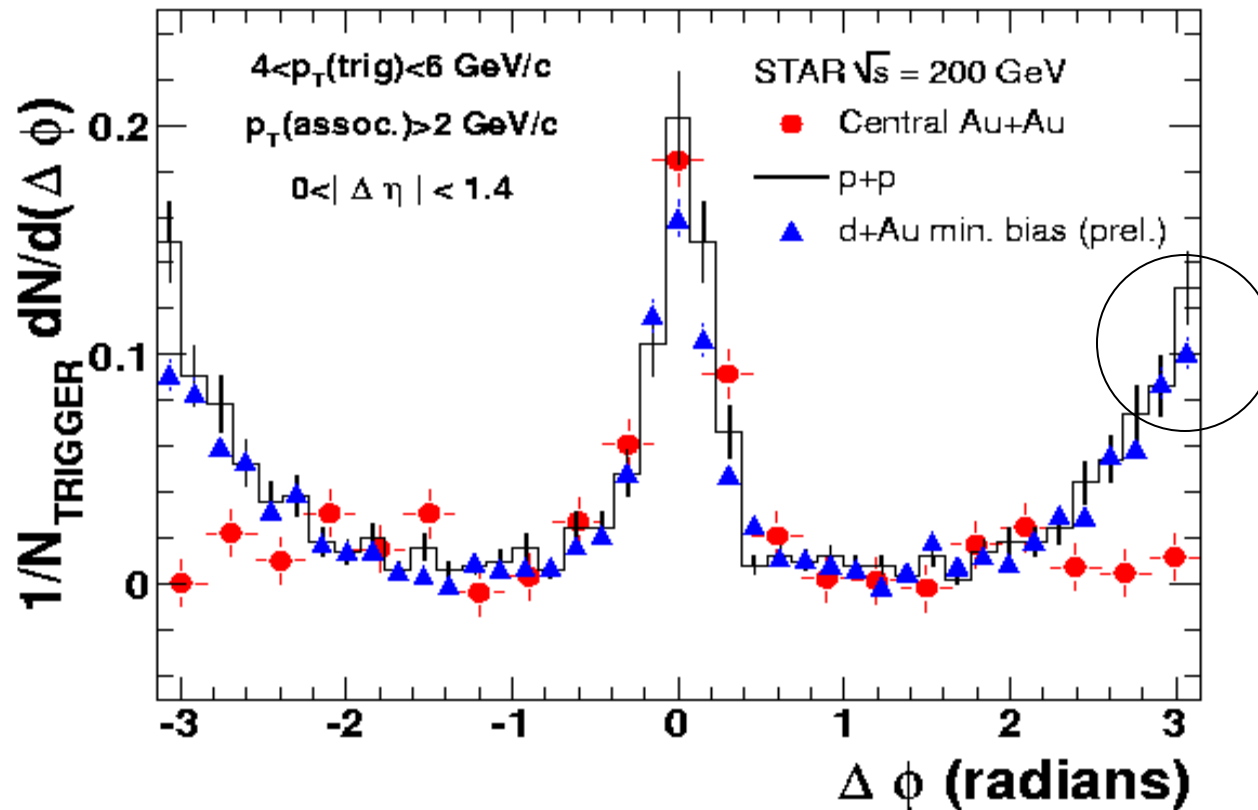
- Trigger particle ("same side")  
 $p_T > 4 \text{ GeV}/c$
- Away-side  
 $2 < p_T < 4 \text{ GeV}/c$
- $\Delta\phi$
- Normalize by number of trigger particles



The away-side jet disappears from p+p to central Au+Au (**hot** nuclear matter).



## Away-Side Jets in p+p, d+Au, and Au+Au Collisions



**Not** disappearing  
in **cold** nuclear matter

## What did we learn so far ?

- $t < 1$  fm/c temperature: beyond lattice-QCD boundary prediction.
- $t < 1$  fm/c energy density: too high for hadron gas.
- parton-hadron transition ("freeze-out") short duration.  
 $R_{\text{out}}/R_{\text{side}} \sim 1$ : There is an explosion
- No indication for 1<sup>st</sup> order phase transition  
(no long-lived slowly-burning mixed quark-hadron soup).
- pQCD models need non-standard extensions,  
i.e. high density and high temperature.
- Back-to-back jets disappear.
- Nature recently exhibits surprising macroscopic phenomena  
(metallic hydrogen, left-handed materials, clockwise tornadoes).  
We will continue to search for microscopic analogons.

# The STAR Collaboration

468 Collaborators

10 Countries

49 Institutions

~20 Ph.D. theses

14 PRL

3 PRC

C. Adler<sup>11</sup>, Z. Ahammed<sup>23</sup>, C. Allgower<sup>12</sup>, J. Amonett<sup>14</sup>, B.D. Anderson<sup>14</sup>, M. Anderson<sup>5</sup>, G.S. Averichev<sup>9</sup>, J. Balewski<sup>12</sup>, O. Barannikova<sup>9,23</sup>, L.S. Barnby<sup>14</sup>, J. Baudot<sup>13</sup>, S. Bekele<sup>20</sup>, V.V. Belaga<sup>9</sup>, R. Bellwied<sup>10</sup>, J. Berger<sup>11</sup>, H. Bichsel<sup>29</sup>, L.C. Bland<sup>12</sup>, C.O. Blyth<sup>3</sup>, B.E. Bonner<sup>24</sup>, R. Bossingham<sup>15</sup>, A. Boucham<sup>28</sup>, A. Brandin<sup>18</sup>, R.V. Cadman<sup>1</sup>, H. Caines<sup>20</sup>, M. Calderón de la Barca Sánchez<sup>31</sup>, A. Cardenas<sup>23</sup>, J. Carroll<sup>15</sup>, J. Castillo<sup>28</sup>, M. Castro<sup>30</sup>, D. Cebra<sup>3</sup>, S. Chattopadhyay<sup>30</sup>, M.L. Chen<sup>2</sup>, Y. Chen<sup>6</sup>, S.P. Chernenko<sup>9</sup>, M. Cherney<sup>8</sup>, A. Chikanian<sup>31</sup>, B. Choi<sup>27</sup>, W. Christie<sup>2</sup>, J.P. Coffin<sup>13</sup>, L. Conin<sup>28</sup>, T.M. Cormier<sup>30</sup>, J.G. Cramer<sup>29</sup>, H.J. Crawford<sup>4</sup>, M. DeMelk<sup>24</sup>, W.S. Deng<sup>14</sup>, A.A. Derevschikov<sup>22</sup>, L. Didenko<sup>2</sup>, J.E. Draper<sup>5</sup>, V.B. Dunin<sup>9</sup>, J.C. Dunlop<sup>31</sup>, V. Eckardt<sup>16</sup>, L.G. Efimov<sup>9</sup>, V. Emelianov<sup>18</sup>, J. Engelage<sup>4</sup>, G. Eppley<sup>24</sup>, B. Erazmus<sup>28</sup>, P. Fachini<sup>25</sup>, V. Faine<sup>2</sup>, E. Finch<sup>31</sup>, Y. Fisyak<sup>2</sup>, D. Flierl<sup>11</sup>, K.J. Foley<sup>2</sup>, J. Fu<sup>15</sup>, N. Gagunashvili<sup>9</sup>, J. Gans<sup>31</sup>, L. Gaudichet<sup>28</sup>, M. Germain<sup>13</sup>, F. Geurts<sup>24</sup>, V. Ghazikhanian<sup>6</sup>, J. Grabski<sup>28</sup>, O. Grachov<sup>30</sup>, D. Greiner<sup>15</sup>, V. Grigoriev<sup>18</sup>, M. Guedon<sup>13</sup>, E. Gushin<sup>18</sup>, T.J. Hallman<sup>2</sup>, D. Hardtke<sup>15</sup>, J.W. Harris<sup>31</sup>, M. Heffner<sup>5</sup>, S. Heppelmann<sup>21</sup>, T. Herston<sup>23</sup>, B. Hippolyte<sup>13</sup>, A. Hirsch<sup>23</sup>, E. Hjort<sup>15</sup>, G.W. Hoffmann<sup>27</sup>, M. Horsley<sup>31</sup>, H.Z. Huang<sup>6</sup>, T.J. Humanic<sup>20</sup>, H. Hümmeler<sup>16</sup>, G. Igo<sup>6</sup>, A. Ishihara<sup>27</sup>, Yu.I. Ivanshin<sup>10</sup>, P. Jacobs<sup>15</sup>, W.W. Jacobs<sup>12</sup>, M. Janik<sup>28</sup>, I. Johnson<sup>15</sup>, P.G. Jones<sup>3</sup>, E. Judd<sup>4</sup>, M. Kaneta<sup>15</sup>, M. Kaplan<sup>7</sup>, D. Keane<sup>14</sup>, A. Kisiel<sup>28</sup>, J. Klay<sup>3</sup>, S.R. Klein<sup>15</sup>, A. Klyachko<sup>12</sup>, A.S. Konstantinov<sup>22</sup>, L. Kotchenda<sup>18</sup>, A.D. Kovalenko<sup>9</sup>, M. Kramer<sup>19</sup>, P. Kravtsov<sup>18</sup>, K. Krueger<sup>1</sup>, C. Kuhn<sup>13</sup>, A.I. Kulikov<sup>9</sup>, G.J. Kunde<sup>31</sup>, C.L. Kunz<sup>7</sup>, R.Kh. Kutuev<sup>10</sup>, A.A. Kuznetsov<sup>9</sup>, L. Lakehal-Ayat<sup>28</sup>, J. Lamas-Valverde<sup>24</sup>, M.A.C. Lamont<sup>3</sup>, J.M. Landgraf<sup>2</sup>, S. Lange<sup>11</sup>, C.P. Lansdel<sup>27</sup>, B. Lasiuk<sup>31</sup>, F. Laue<sup>2</sup>, A. Lebedev<sup>2</sup>, T. LeCompte<sup>1</sup>, R. Lednický<sup>9</sup>, V.M. Leontiev<sup>22</sup>, M.J. LeVine<sup>2</sup>, Q. Li<sup>30</sup>, Q. Li<sup>15</sup>, S.J. Lindenbaum<sup>19</sup>, M.A. Lisa<sup>20</sup>, T. Ljubicic<sup>2</sup>, W.J. Llope<sup>24</sup>, G. LoCurto<sup>16</sup>, H. Long<sup>6</sup>, R.S. Longacre<sup>2</sup>, M. Lopez-Noriega<sup>20</sup>, W.A. Love<sup>2</sup>, D. Lynn<sup>2</sup>, R. Majka<sup>31</sup>, S. Margets<sup>14</sup>, L. Martin<sup>28</sup>, J. Marx<sup>15</sup>, H.S. Matis<sup>15</sup>, Yu.A. Matulenko<sup>22</sup>, T.S. McShane<sup>8</sup>, F. Meisner<sup>15</sup>, Yu. Melnick<sup>22</sup>, A. Meschanin<sup>22</sup>, M. Messer<sup>2</sup>, M.L. Miller<sup>28</sup>, Z. Miksevich<sup>7</sup>, N.G. Minaev<sup>22</sup>, J. Mitchell<sup>24</sup>, V.A. Moiseenko<sup>10</sup>, D. Moltz<sup>15</sup>, C.F. Moore<sup>27</sup>, V. Morozov<sup>15</sup>, M.M. de Moura<sup>30</sup>, M.G. Munhoz<sup>25</sup>, G.S. Mutchler<sup>24</sup>, J.M. Nelson<sup>3</sup>, P. Nevskiy<sup>2</sup>, V.A. Nikitin<sup>10</sup>, L.V. Nogach<sup>22</sup>, B. Norman<sup>14</sup>, S.B. Nurushev<sup>22</sup>, G. Odyniec<sup>15</sup>, A. Ogawa<sup>21</sup>, V. Okorokov<sup>18</sup>, M. Oldenhug<sup>16</sup>, D. Olson<sup>15</sup>, G. Pak<sup>20</sup>, S.U. Pandey<sup>30</sup>, Y. Panebratsev<sup>9</sup>, S.Y. Panitkin<sup>2</sup>, A.I. Pavlinov<sup>20</sup>, T. Pawlak<sup>28</sup>, V. Perevoztchikov<sup>2</sup>, W. Peryt<sup>28</sup>, V.A. Petrov<sup>10</sup>, W. Pingaud<sup>28</sup>, E. Platner<sup>24</sup>, J. Pluta<sup>28</sup>, N. Porile<sup>23</sup>, J. Porter<sup>2</sup>, A.M. Poskanzer<sup>15</sup>, E. Potrebennikova<sup>9</sup>, D. Prindle<sup>29</sup>, C. Pruneau<sup>30</sup>, S. Radomski<sup>28</sup>, G. Rai<sup>15</sup>, O. Ravel<sup>28</sup>, R.L. Ray<sup>27</sup>, S.V. Razin<sup>9,12</sup>, D. Reichhold<sup>8</sup>, J.G. Reid<sup>29</sup>, F. Retiere<sup>15</sup>, A. Ridiger<sup>18</sup>, H.G. Ritter<sup>15</sup>, J.B. Roberts<sup>24</sup>, O.V. Rogachevski<sup>9</sup>, J.L. Romero<sup>3</sup>, C. Roy<sup>26</sup>, D. Russ<sup>7</sup>, V. Rykov<sup>30</sup>, I. Sakrejda<sup>15</sup>, J. Sandweiss<sup>15</sup>, A.C. Saulys<sup>2</sup>, I. Savin<sup>10</sup>, J. Schambach<sup>27</sup>, R.P. Scharenberg<sup>23</sup>, K. Schweda<sup>15</sup>, N. Schmitz<sup>16</sup>, L.S. Schroeder<sup>15</sup>, A. Schütttauf<sup>16</sup>, J. Seger<sup>8</sup>, D. Seliverstov<sup>18</sup>, P. Seyboth<sup>16</sup>, E. Shalaliev<sup>9</sup>, K.E. Shestermanov<sup>22</sup>, S.S. Shimanskiy<sup>9</sup>, V.S. Shvetcov<sup>10</sup>, G. Skoro<sup>9</sup>, N. Smirnov<sup>31</sup>, R. Snellings<sup>15</sup>, J. Sowinski<sup>12</sup>, H.M. Spinka<sup>1</sup>, B. Srivastava<sup>23</sup>, E.J. Stephenson<sup>12</sup>, R. Stock<sup>11</sup>, A. Stolpovsky<sup>30</sup>, M. Strikhanov<sup>18</sup>, B. Stringfellow<sup>23</sup>, H. Stroebele<sup>11</sup>, C. Struck<sup>11</sup>, A.A.P. Suaid<sup>20</sup>, E. Sugarbaker<sup>20</sup>, C. Suire<sup>13</sup>, M. Sumera<sup>9</sup>, T.J.M. Symons<sup>15</sup>, A. Szanto de Toledo<sup>25</sup>, P. Szarwas<sup>28</sup>, J. Takahashi<sup>25</sup>, A.H. Tang<sup>14</sup>, J.H. Thomas<sup>15</sup>, V. Tikhomirov<sup>18</sup>, T.A. Trainor<sup>29</sup>, S. Trentalange<sup>8</sup>, M. Tokarev<sup>9</sup>, M.B. Tonjes<sup>17</sup>, V. Trofimov<sup>18</sup>, O. Tsai<sup>6</sup>, K. Tumer<sup>2</sup>, T. Ullrich<sup>2</sup>, D.G. Underwood<sup>4</sup>, G. Van Buren<sup>7</sup>, A.M. VanderMolen<sup>17</sup>, A. Vanyashin<sup>15</sup>, I.M. Vasilievski<sup>10</sup>, A.N. Vasiliev<sup>22</sup>, S.E. Vigdor<sup>12</sup>, S.A. Voloshin<sup>30</sup>, F. Wang<sup>23</sup>, H. Ward<sup>27</sup>, J.W. Watson<sup>14</sup>, R. Welk<sup>20</sup>, T. Wenaus<sup>2</sup>, G.D. Westfall<sup>17</sup>, C. Whitten Jr.<sup>6</sup>, H. Wieman<sup>15</sup>, R. Willson<sup>20</sup>, S.W. Wissink<sup>12</sup>, R. Witt<sup>14</sup>, N. Xu<sup>15</sup>, Z. Xu<sup>11</sup>, A.E. Yakutin<sup>22</sup>, E. Yamamoto<sup>9</sup>, J. Yang<sup>6</sup>, P. Yepes<sup>24</sup>, A. Yokosawa<sup>1</sup>, V.I. Yurevich<sup>9</sup>, Y.V. Zanevski<sup>9</sup>, I. Zborovskiy<sup>9</sup>, W.M. Zhang<sup>14</sup>, R. Zoukarninev<sup>10</sup>, A.N. Zubarev<sup>9</sup>